Network Competition and Network Regulation

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Working Paper N° 13
ISBN 987-519-090-X
(July 2001)

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CEER Working Paper Series

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(July 2001)
JEL N°: L5, L9

Abstract:
The competitive structure of the telecommunication sector is changing all over the world. Competition is being introduced in the long-distance segments while the local markets remain in general under the control of a (group of) regulated monopolies. This paper tries to find the optimal regulation in the monopoly sector and the optimal access price, taking into account the effects of the competition between networks, any access price plays a role in that it allows the regulator to indirectly control prices in the unregulated segment. We show that, there is no loss of generality in making the access pcices for originating or terminating a call equal. Moreover, under complete information, if networks are poor substitutes, the optimal access price is lower than the marginal cost of access. Under asymmetric information, two effects work in opposite directions. On the one hand, access price is reduced with respect to marginal cost to induce a reduction in final price. On the other hand, access price is increased with respect to marginal cost to give incentives to reveal information.

Acknowledgments for helpful comments:
I'm grateful to J. J. Laffont and P. Rey for their useful comments. Any remaining mistake is my own responsibility.

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1. Introduction

Competition in telecommunications is becoming more and more widespread. The industry that was considered as a natural monopoly, is now viewed as a multiproduct sector where some products (typically the local calls sector) are subject to (large) economies of scale, while other products could be competitive. The result is then the coexistence within the same firms of a regulated sector and a competitive one. The case of Argentina is a good example of this trend. In 1989 the national telecommunications monopoly was privatized into two separated (and regulated) regional monopolies. This monopoly position was guaranteed for the 10 first years after the privatization[1]. In 1999 competition between the two operators was allowed for long-distance calls. Moreover, two new operators entered the market to serve this segment. As a consequence, the two incumbents are still regulated for local calls (each of them is still a monopoly) while all networks freely compete in linear prices in the long-distance segment. Nevertheless, the regulator still has some influence over those prices through the regulation of the access price. The objective of this paper is to build a model that could represent this situation and to study the optimal regulation of the local segment and of the access price given the competition generated in the long-distance segment.

The model will be developed combining two different aspects of network competition in the existing literature. The first is the regulation of a single network under incomplete information when it faces competition in some services. This is the approach followed by Laffont and Tirole (1997). In their model, a single network, the incumbent, is regulated in both local and long-distance calls and a perfectly competitive fringe is available for the latter. They determine then the optimal regulation of local, long-distance calls and access. There are two main differences between their model and the one in this paper. On the one hand, they are considering a fully regulated monopoly. That is, even if there is competition for the long-distance segment, the incumbent cannot freely determine the price it wants to charge for this service[2]. On the other hand, there is no network competition in their model. The competitive fringe needs access to sell its product and then access is only one-way. On the contrary, our model has two networks that have to be interconnected to each other and then access is here two-ways.

The second related model is the one developed by Laffont, Rey and Tirole (1998a) and (1998b), which assumes two competing and unregulated networks. In their framework two different networks compete in the unique product they sell to final consumers. In contrast with our model, their objective is to study how network competition will actually take place. They marginally investigate what would be the optimal access price with complete information. Our model, therefore, goes further in that it introduces a second regulated segment and analyzes the optimal regulatory policy under incomplete information.

In this paper we show that, in general, the optimal access price is different from the marginal cost of providing access. The reason is that without perfect competition in the

[1] Actually, the guarantee was for the 7 first years but with a possible extension of 3 years if some goals were achieved.

[2] They also discuss what would be the impact of restricting regulation only to the segment that is not competitive.

long-distance segment, it is optimal to introduce a distortion in the access price in order to overcome the distortion generated by the market power of the networks. Moreover, with such a policy, the regulator can replicate the second-best policy that would have resulted from having a fully regulated monopoly.

2. The general setup

Two networks provide two different kinds of services: local calls (good 0) and long-distance calls. Each network is a monopoly in the provision of local calls, but both compete with each other in the market of long-distance calls (good 1). For the market of local calls, consumers are allocated regionally to each network, in such a way that local calls are always from one network to itself. For long-distance calls, each network provides interior calls (good *i*) and exterior calls (good *e*). As a benchmark we will consider the case where consumers cannot choose between the two networks for long-distance calls. We will assume in that case that each network is completely regulated. The characteristics of the market are described in what follows.

Demand structure: We assume that the demands for local and long-distance calls are independent of each other. To simplify, we assume a balanced calling pattern. This assumption implies that the probability of a call to finish on-net or off-net is equal to the market share of the originating or terminating network. Networks are differentiated à la Hotelling. There is a continuum of customers with unit mass uniformly distributed on the segment [0,1] and each network is located at one of the extremes: network 1 is located at $x^1 = 0$ and network 2, at $x^2 = 1$[3]. For local calls, half of the consumers are assigned to each network. Each customer has to pay a transportation cost if he is not able to subscribe to his most preferred network. The utility of a customer located at x subscribing to network *j* is then:

$$y + z + u_0\left(q_0^j\right) + \alpha^j u_1\left(q_i^j\right) + \alpha^k u_1\left(q_e^j\right) - \tau\left|x - x^j\right|$$

where y is the consumer's income, z is the (fixed) utility of being connected to the system, α^j is the market share of network *j*, $u_l(q_l^j)$ is the utility derived from consuming q^j of good l and τ is the per unit of distance transportation cost. We will assume that $u_l' > 0$, $u_l'' < 0$ and $u_l''' < 0$, $l = 0,1$[4]. All along the paper, it is assumed that z is large enough, so that all the consumers are connected to one network.

Consumers, then, maximize their utility given the prices of all the goods. The corresponding indirect utility functions are:

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[3] It should be stressed that the dimension of differentiation is completely orthogonal to the real geographical position of the networks, so the consumer located at x = 0 may belong to network 2 for local calls.

[4] In fact, $u_l''' < 0$ is too strong an assumption. For instance, with a constant elasticity utility function with demand elasticity equal to η, it is always true that the third derivative is positive. Nevertheless, all the conclusions are still valid because $\eta > \lambda / (1 + \lambda)$.

$$v_0\left(p_0^j\right)=\max_{q_0^j}\left\{u_0\left(q_0^j\right)-p_0^j q_0^j\right\}$$
$$v_1\left(p_i^j\right)=\max_{q_i^j}\left\{u_1\left(q_i^j\right)-p_i^j q_i^j\right\}$$
$$v_1\left(p_e^j\right)=\max_{q_e^j}\left\{u_1\left(q_e^j\right)-p_e^j q_e^j\right\}$$

Cost structure: We assume that the marginal cost of the local loop for network j is c_0^j. The long-distance calls create and additional marginal cost equal to c_1 for any network which is always paid by the originating network. All technologies exhibit constant returns to scale, except for a fixed cost f that has to be incurred for each customer that is connected to a network. On the other hand, each network charges an originating access charge, a_o^j and a terminating access charge a_t^j, for the completion of calls of clients subscribing the other network.

We assume that networks are obliged to charge the same price for interior or exterior calls[5], then $p_i^j = p_e^j = p_1^j$. In Figure 1 we show the unit profit for network 1 (located in the north for local calls), for a long-distance call according to the region in which it is originated and terminated.

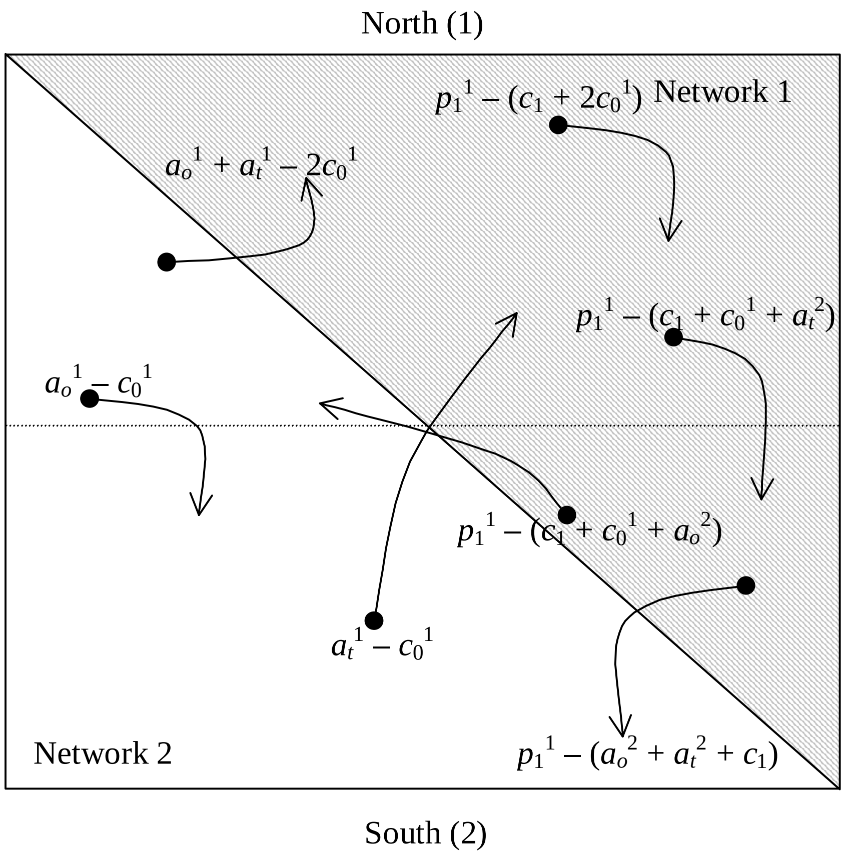

Figure 1: Unit profit of network 1

[5] Actually, that is what happens in Argentina.

Defining t^j as a transfer received by the firm from the government, the profit function of network *j* can be written as:

$$\pi^j = \frac{1}{2}\left[\left(p_0^j - c_0^j\right)q_0^j - f\right] + \frac{1}{4}\alpha^j\left(p_1^j - 2c_0^j - c_1\right)q_1^j + \frac{1}{4}\alpha^j\left(p_1^j - c_0^j - c_1 - a_t^k\right)q_1^j$$
$$+\frac{1}{4}\alpha^j\left(p_1^j - c_0^j - c_1 - a_o^k\right)q_1^j + \frac{1}{4}\alpha^j\left(p_1^j - c_1 - a_o^k - a_t^k\right)q_1^j \qquad (1)$$
$$+\frac{1}{4}\alpha^k\left(a_o^j + a_t^j - 2c_0^j\right)q_1^k + \frac{1}{4}\alpha^k\left(a_o^j - c_0^j\right)q_1^k + \frac{1}{4}\alpha^k\left(a_t^j - c_0^j\right)q_1^k + t^j$$

The first term is the profit made on local calls. The following terms are the profits made on long-distance calls originated in network *j*, which depend on the access charges of network *k*. Finally, the last three terms are the profits made on access provided to network *k*, which depends on the number of long-distance calls originated in network *k*.

It will be useful to rewrite equation (1) as

$$\pi^j = \frac{1}{2}\left[\left(p_0^j - c_0^j\right)q_0^j - f\right] + \alpha^j\left(p_1^j - 2c_0^j - c_1\right)q_1^j$$
$$+\frac{1}{4}\alpha^k\left(a_o^j + a_t^j - 2c_0^j\right)q_1^k - \frac{1}{2}\alpha^j\left(a_o^k + a_t^k - 2c_0^j\right)q_1^j + t^j$$

So the first two terms are the retail profit and the following two are access revenue or deficit.

3. Regulation of two regional monopolies: A benchmark

As a benchmark, we assume in this section that there is no competition neither in the local segment nor in the long-distance segment. Consumers are obliged to subscribe to its local provider for long-distance calls, so $\alpha^1 = \alpha^2 = 1/2$. Then, the consumers' indirect utility function and the networks' profit functions write in this framework:

$$S\left(p_0^j, p_1^j\right) = v_0\left(p_0^j\right) + v_1\left(p_1^j\right)$$
$$\pi^j = t^j + \frac{1}{2}\left[\left(p_0^j - c_0\right)q_0^j - f + \left(p_1^j - 2c_0 - c_1\right)q_1^j\right] \qquad (2)$$
$$+\frac{1}{4}\left[\left(a_o^j + a_t^j - 2c_0\right)q_1^k - \left(a_o^k + a_t^k - 2c_0\right)q_1^j\right]$$

3.1 Complete information

We assume first that all the relevant information about the cost structure is available to the regulator and that $c_0^1 = c_0^2 = c_0$. Assuming an utilitarian regulator and a cost of public funds equal to λ, the regulator's problem is:

$$\max_{\left(p_0^j, p_1^j, t^j\right)} \sum_{j=1}^{2} \left\{ \frac{1}{2} S\left(p_0^j, p_1^j\right) - (1+\lambda) t^j + \pi^j \right\}$$

subject to

$$\pi^j \geq 0 \qquad\qquad j = 1,2$$

Proposition 1. *The optimal pricing is a Ramsey pricing structure. Prices of local calls and long-distance calls are symmetric for both networks and given by* $p_0^1 = p_0^2 = p_0$ *and* $p_1^1 = p_1^2 = p_1$ *such that:*

$$\frac{p_0 - c_0}{p_0} = \frac{\lambda}{1+\lambda} \frac{1}{\eta_0}$$

$$\frac{p_1 - 2c_0 - c_1}{p_1} = \frac{\lambda}{1+\lambda} \frac{1}{\eta_1}$$

where η_0 *is the demand elasticity of local calls and* η_1 *is the demand elasticity of long-distance calls.*

Proof. The first thing that can be observed is that the only relevant variable is the sum of the access charges. Second, social welfare is independent of the access charges. Because the access deficit of a network equals the access revenue of the other network, access payments are just transfers from one network to the other, and those transfers do not create any distortion through the tax system. Therefore, the relevant marginal cost for off-net calls is the true marginal cost $2c_0 + c_1$, which is equal to the marginal cost of on-net calls. The rest of the proof is standard: the regulator sets (t^1, t^2) such that profits are equal to zero and then optimizes with respect to prices. QED.

Of course, under complete information, if the regulator can control all the prices, and given that transfers are costly, the best she can do is to distort the prices over the marginal cost proportionally to the inverse of the demand elasticity. The magnitude of the distortion increases when the cost of the transfers increases.

Ramsey prices are the first-best solution and are implementable under complete information.

3.2 Incomplete information

Of course, it is well known that the regulator usually is not able to observe the cost structure of the regulated firm. In that case, Ramsey prices are no longer implementable and, therefore, a second-best solution has to be found.

So, let us assume now that the regulator cannot observe the cost structure of the networks. For simplicity we assume that the regulator observes the long-distance marginal cost, c_1. However, the local marginal cost c_0 is private information of the networks. More specifically we assume that it is common knowledge that each network's local marginal cost is independently drawn from the same cdf function $F(c_0^j)$ on the support $\Omega = [\underline{c}_0, \bar{c}_0]$.

Assumption 1. *Monotone hazard rate: We assume that* $\frac{d}{dc_0^j}\left(\frac{F(c_0^j)}{f(c_0^j)}\right) > 0$.

For the rest of the paper we define $\pi^j(\tilde{c}_0^j, \tilde{c}_0^k, c_0^j, c_0^k)$, the profit of network j when the true cost vector is (c_0^j, c_0^k) but firms announce $(\tilde{c}_0^j, \tilde{c}_0^k)$, and $\pi^j(c_0^j, c_0^k) \equiv \pi^j(c_0^j, c_0^k, c_0^j, c_0^k)$, the profit when both firms are truthful.

From the revelation principle we know that the regulator can restrict its attention to direct revelation mechanisms in which agents are induced to truthfully reveal their private information. Then, we have to add to the maximization problem the incentive compatibility constraints. The regulator's problem, then, writes:

$$\max_{(p_0^j, p_1^j, t^j)_{j=1,2}} E_{c_0^1, c_0^2}\left[\sum_{j=1}^{2}\left\{\frac{1}{2}S(p_0^j, p_1^j) - (1+\lambda)t^j + \pi^j\right\}\right]$$

subject to

$$E_{c_0^k}\pi^j(c_0^j, c_0^k) \geq E_{c_0^k}\pi^j(\tilde{c}_0^j, \tilde{c}_0^k, c_0^j, c_0^k), \forall(\tilde{c}_0^j, c_0^j) \in \Omega^2,\ j = 1,2$$

$$E_{c_0^k}\pi^j(c_0^j, c_0^k) \geq 0, \forall c_0^j \in \Omega,\ j = 1,2$$

The incentive and participation constraints are interim, because network j only knows c_0^j but not c_0^k.

Proposition 2. *Under assumption 1, the optimal regulatory contract offered to both networks is given by:*

$$\frac{p_0^j(c_0) - c_0^j}{p_0^j(c_0)} = \frac{\lambda}{1+\lambda}\frac{1}{\eta_0} + \frac{\lambda}{1+\lambda}\frac{1}{p_0^j(c_0)}\frac{F(c_0^j)}{f(c_0^j)}$$

$$\frac{p_1^j - c^{jk}}{p_1^j} = \frac{\lambda}{1+\lambda}\frac{1}{\eta_1} + \frac{\lambda}{1+\lambda}\frac{1}{p_1^j(c_0)}\left[\frac{F(c_0^j)}{f(c_0^j)} + \frac{F(c_0^k)}{f(c_0^k)}\right]$$

where $c^{jk} = c_0^j + c_0^k + c_1$.

Proof. See appendix.

Notice first that the average marginal cost of a long-distance call is given by $1/4(c^{11} + 2c^{12} + c^{22}) = c^{12} = c^{21}$. To induce the networks to reveal their marginal cost, prices are distorted upwards (quantities are distorted downwards) except if both networks are efficient: $c_0^1 = c_0^2 = \underline{c}_0$. For the local segment, the pricing structure is standard under incomplete information: goods are independent, so the existence of a second network does not affect the optimal regulation. Because the marginal cost of the networks can differ now, the marginal cost of an exterior call could differ from the marginal cost of an interior call. Furthermore, because networks are interconnected even if network j is efficient ($c_0^j = \underline{c}_0$), if network k is less efficient, then p_1^j will be upward distorted. The reason is that the number of exterior calls of network j affects the rent that has to be given to a more efficient network k. In order to decrease this rent, the regulator distorts downward all the quantities produced by network k plus the quantity of exterior calls originated in network j.

We have ignored here the possibility of collusion between networks. Indeed, one can imagine that networks could coordinate their reports to the regulator and jointly announce a cost vector different from the true one in order to obtain a higher rent. However, as Laffont and Martimort (1998) have shown, the optimal contract is collusion-proof when costs are independent and collusion occurs under asymmetric information between the networks. This means that this second-best contract satisfies the coalition incentive constraints, so networks can never gain by coordinating to announce a false cost vector and, therefore, collusion is not an issue in our framework.

4. Duopoly: Competition and regulation under complete information

We will assume in this section that, while the local segment remains monopolized, competition between the networks is allowed in the long-distance segment. Each consumer will decide to which network he will subscribe for his long-distance calls. We will assume also that the regulator will determine only the prices for local calls and the access (originating and terminating) prices, while competition between networks will determine the prices of long-distance calls. The timing is as follows:

- The regulator offers a contract $\Gamma^j = \{p_0^j, a_o^j, a_t^j, t^j\}$ to network j.
- Simultaneously both networks accept or reject the contract.
- If a network rejects it receives its status-quo utility, which is assumed to be equal to 0 and independent of the type.
- If network j accepts it will set prices for the long-distance segment p_1^j. This choice is simultaneous if both firms have accepted the contract.
- We are looking for a subgame perfect Nash equilibrium.

4.1 The problem of the firm

Given the regulatory policy Γ^j network j will maximize its profit. Profit of network j is defined as in equation (1).

We define α by the location of the consumer who is indifferent between both networks for long-distance calls:

$$v_1(p_1^j) - \tau\alpha = v_1(p_1^k) - \tau(1-\alpha)$$

or equivalently:

$$\alpha = \frac{1}{2} + \sigma\left[v_1(p_1^j) - v_1(p_1^k)\right] \qquad (3)$$

where $\sigma = 1/2\tau$ is a measure of the degree of substitutability between the networks.

So, in a shared market equilibrium, all customers located to the left of α will connect to network 1 and all the others, to network 2, therefore, $\alpha^1 = \alpha$ and $\alpha^2 = 1 - \alpha$.

The profit maximization first order condition for network j is then:

$$\frac{\partial\alpha^j}{\partial p_1^j}\left[\left(p_1^j-2c_0^j-c_1\right)q_1^j-\frac{1}{2}\left(a_o^k+a_t^k-2c_o^j\right)q_1^j\right]+\frac{1}{2}\frac{\partial\alpha^k}{\partial p_1^j}\left(a_o^j+a_t^j-2c_o^j\right)q_1^k$$
$$+\alpha^j\left[q_1^j+\left(p_1^j-2c_0^j-c_1\right)\frac{\partial q_1^j}{\partial p_1^j}-\frac{1}{2}\left(a_o^k+a_t^k-2c_o^j\right)\frac{\partial q_1^j}{\partial p_1^j}\right]=0$$

Proposition 3. *For either $a_o + a_t$ close to $2c_0$ or σ small enough, it exists a unique shared market equilibrium, which is symmetric, with prices of on-net and off-net calls given by:*

$$\frac{p_1^*-c-\frac{a_o+a_t-2c_0}{2}}{p_1^*}=\frac{1}{\eta_1}\left[1-2\sigma\pi\left(p_1^*\right)+2\sigma(a_o+a_t-2c_0)q_1^*\right] \qquad (4)$$

where $\pi(p_1) = (p_1 - c)\, q_1(p_1)$, $\eta_1=-\frac{\partial q_1}{\partial p_1}\frac{p_1}{q_1}$.

Proof. The proof follows the same steps as the one in Laffont et al. (1998a).

It is easy to compare equation (4) with the standard monopoly pricing structure, given by $\frac{p^M-c}{p^M}=\frac{1}{\eta_1}$. The first difference is that the true marginal cost is replaced by the perceived marginal cost, which in per customer terms is equal to $c+\frac{a_o+a_t-2c_0}{2}$. The second difference is related to σ, the degree of substitutability between the networks. An increase in the price of the long-distance calls lowers market share by σ times sales per customer, q_1. This decrease in market share lowers firm j's profits in the symmetric equilibrium by $\left(p_1-c-\frac{a_o+a_t-2c_0}{2}\right)q_1$ for the customers belonging to network j and increases firm j's profits by $\frac{a_o+a_t-2c_0}{2}q_1$ for the customers of network k that need access to j's local loop. Therefore, the total decrease in profit generated by a decrease in market share is given by $(p_1-c)q_1-(a_o+a_t-2c_0)q_1$.

For the rest of the paper, and only to simplify, we will assume a constant elasticity demand function both for local and long distance calls.

$$u_0(q_0)=\frac{q_0^{1-\frac{1}{\eta_0}}}{1-\frac{1}{\eta_0}}\Leftrightarrow q_0(p_0)=p_0^{-\eta_0},\ \eta_0>1$$
$$u_1(q_1)=\frac{q_1^{1-\frac{1}{\eta}}}{1-\frac{1}{\eta}}\Leftrightarrow q_1(p_1)=p_1^{-\eta},\ \eta>1$$

This allows us to obtain explicit solutions without affecting the qualitative results, which remain valid for any utility function satisfying the assumptions of Section 2.

4.2 The regulator's problem

In the first stage, the regulator will choose the contracts that maximize social welfare, taking into account the outcome of the competition game. Because the regulator wants both networks to accept the contract, it will have to add a participation constraint: the firm can always reject the contract and get 0 outside the relationship. This participation constraint in the symmetric equilibrium is equal to:

$$t+\frac{1}{2}[(p_0-c_0)q_0-f]+\frac{1}{2}\left(p_1^*-2c_0-c_1\right)q_1^*\geq 0 \qquad (5)$$

Using (4), the regulator's problem, thus, writes:

$$\max_{(p_0,a_0,a_t,t)} v_0(p_0)+v_1\left(p_1^*\right)-2(1+\lambda)t+2\pi \qquad (6)$$

subject to (5).

Because of the cost of publics funds, λ, transfers are costly, which implies that the participation constraint will be binding at the optimum.

Proposition 4. *For σ small, and constant elasticity demand functions, the optimal regulatory contract satisfies:*

$$\frac{p_0-c_0}{p_0}=\frac{\lambda}{1+\lambda}\frac{1}{\eta_0} \qquad (7)$$

$$a_0+a_t<2c_0 \qquad (8)$$

The regulator can fix one of the access charges at the level it wants, because only the sum is determined at the optimum. Then, without loss of generality, she can fix $a_o = a_t$.

Proof. Condition (7) results immediately by taking the first order conditions in (6) with respect to p_0 and noting that this variable does not affect the competitive outcome. To obtain condition (8), assume $\sigma = 0$ (by continuity, the qualitative results also hold for σ small). Then, from (4),

$$\frac{p_1^*-c-\dfrac{a_o+a_t-2c_0}{2}}{p_1^*}=\frac{1}{\eta_1}$$

and so, $\frac{\partial p_1^*}{\partial a_o}=\frac{\partial p_1^*}{\partial a_t}=\frac{1}{2}\frac{\eta}{\eta-1}\neq 0$. Taking the first order conditions with respect to a_o gives:

$$\left\{\frac{\partial v_1}{\partial p_1}+(1+\lambda)\left[q_1+\left(p_1^*-2c_0-c_1\right)\frac{\partial q_1^*}{\partial p_1}\right]\right\}\frac{\partial p_1^*}{\partial a_0}=0$$

By the envelope theorem, $\frac{\partial v_1}{\partial p_1}=-q_1(p_1)$. Using this condition and rearranging gives:

$$a_0 + a_t = 2c_0 - \frac{2}{1+\lambda}\frac{p_1^*}{\eta} < 2c_0 \qquad (9)$$

The first order condition with respect to a_t gives the same result. Then, only the sum of the two access charges is determined and the regulator has one degree of freedom in choosing a_o and a_t. QED

Because the price in the competitive segment decreases with a_o (or a_t), the regulator wants to reduce the access charges under the marginal cost of giving access in order to induce a reduction in the price of the competitive segment. Moreover, by setting the access charges according to equation (9), the regulator is able to obtain the Ramsey price for the competitive segment when $\sigma = 0$. In general, the regulator will choose $a_o + a_t$ to get the Ramsey structure. This very strong result comes from the fact that access charges do not matter from a social point of view by themselves, because they create a transfer that does not generate any distortion through the tax system. They only matter as long as they can change the final price in the long distance segment.

5. Competition and regulation under incomplete information

In this section we will assume that the marginal cost is private information of each network. As in Section 3.2 we assume that the long-distance marginal cost is common knowledge and is the same for both networks. On the other hand, the local marginal cost c_0^j for each network is independently drawn from the same cdf $F(c_0^j)$ on the support Ω.

We consider the same timing as in the previous section.

- The regulator offers a mechanism to each network that will determine $(t^j, p_0^j, a_o^j, a_t^j)$, $j = 1,2$ as a function of $\tilde{c}_0 = \left(\tilde{c}_0^1, \tilde{c}_0^2\right)$.

- Simultaneously both networks accept or reject the mechanism.

- If a network rejects it receives its status-quo utility, which is assumed to be equal to 0 and independent of the type.

- If network j accepts, it announces a marginal cost $\tilde{c}_0^j$. Then, it will set prices for the long-distance segment (p_1^j). This choice is simultaneous if both firms have accepted the contract.

- Transfers are implemented according to the mechanism.

Some comments have to be made with respect to this timing. For instance, if the choice of the contract is simultaneous with the competition between networks, then competition would occur under asymmetric information: when network j sets its prices for long-distance calls, it does not know c_0^k. If, on the contrary, the networks were to (publicly) choose the contract before they compete in the long-distance market, competition would happen under symmetric information. This implies that we cannot simply apply the revelation principle, because the revelation of the private information will implicitly change the outcome of the competition game. However, because we are trying to reproduce the Argentinean situation, we will assume that the regulator commits to reveal any information it acquires. Therefore, we know that firm will compete under symmetric information.

5.1 Competition under symmetric information

In this first case, the regulator offers $\{t^j(\tilde{c}_0), p_0^j(\tilde{c}_0), a_o^j(\tilde{c}_0), a_t^j(\tilde{c}_0)\}$, a direct revelation mechanism, and asks the networks to select the contract before competition starts in the long-distance segment. This implies that the networks will compete under complete information. In particular, each network will know the other network's local marginal cost and, therefore, the access prices it will face. Given the revelation game and the information it gets about network k[6], network \$j\$ will choose p_1^j so as to maximize:

$$\pi^j = \frac{1}{2}\left[\left(p_0^j - c_0^j\right)q_0^j - f\right] + \alpha^j\left(p_1^j - 2c_0^j - c_1\right)q_1^j$$
$$+\frac{1}{4}\alpha^k\left(a_o^j + a_t^j - 2c_0^j\right)q_1^k - \frac{1}{2}\alpha^j\left(a_o^k + a_t^k - 2c_0^j\right)q_1^j + t^j$$

The regulator will use the Nash equilibrium of the competition game to determine the optimal access prices.

If we assume that $\sigma = 0$, then, the solution of the competitive game is to price at the monopoly level, given the perceived marginal cost. Prices are, then given by:

$$\frac{p_1^j - c^{jk} - \dfrac{a_o^k + a_t^k - 2c_0^k}{2}}{p_1^j} = \frac{1}{\eta} \quad (10)$$

The regulator will then choose the best contract given this competition that would be generated ex-post. It will then maximize the expected social welfare under the incentive compatibility constraints, the rationality constraints and equations (10).

The Bayesian incentive compatibility constraints are given by:

$$E_{c_0^k}\left(\frac{d\pi^j}{dc_0^j}\right) = -\frac{1}{2}E_{c_0^k}\left[q_0^j(c_0) + q_1^j(c_0) + q_1^k(c_0)\right] \qquad (11)$$

$$E_{c_0^k}\left(\frac{\partial^2\pi^j}{\partial c_0^j \partial\tilde{c}_0^j}\right) \geq 0 \qquad (12)$$

Then, we have the following result.

Proposition 5. *When* $\sigma = 0$ *the optimal regulatory contract, given that competition works under complete information between the networks, is given by:*

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[6] Each network knows that the other network is going to tell the truth about its marginal cost because the revelation game satisfies the incentive compatibility constraints.

$$\frac{p_0^j(c_0)-c_0^j}{p_0^j(c_0)}=\frac{\lambda}{1+\lambda}\frac{1}{\eta_0}+\frac{\lambda}{1+\lambda}\frac{1}{p_0^j(c_0)}\frac{F(c_0^j)}{f(c_0^j)} \quad (13)$$

$$\frac{p_1^j-c^{jk}}{p_1^j}=\frac{\lambda}{1+\lambda}\frac{1}{\eta_1}+\frac{\lambda}{1+\lambda}\frac{1}{p_1^j(c_0)}\left[\frac{F(c_0^j)}{f(c_0^j)}+\frac{F(c_0^k)}{f(c_0^k)}\right] \quad (14)$$

Once again, only the sum of the two access charges can be determined. Therefore, the regulator has one degree of freedom in choosing the access charges.

Indeed,

$$a_o^j+a_t^j=2c_0^j+\frac{2}{\lambda(\eta-1)+\eta}\left[\lambda(\eta-1)\left(\frac{F(c_0^j)}{f(c_0^j)}+\frac{F(c_0^k)}{f(c_0^k)}\right)-c^{jk}\right] \qquad (15)$$

Proof. Following the steps of the proof of Proposition 2, the regulator solves:

$$\max \iint_{\Omega^2}\{\frac{1}{2}S(p_0^1,p_1^1)+\frac{1}{2}S(p_0^2,p_1^2)+\frac{1}{2}(1+\lambda)[(p_0^1-c_0^1)q_0^1+(p_1^1-c_1^{11})q_1^1-f]$$
$$+\frac{1}{2}(1+\lambda)[(p_0^2-c_0^2)q_0^2+(p_1^2-c_1^{22})q_1^2-f]-\frac{\lambda}{2}[q_0^1\frac{F(c_0^1)}{f(c_0^1)}+q_0^2\frac{F(c_0^2)}{f(c_0^2)}$$
$$+\left(\frac{F(c_0^1)}{f(c_0^1)}+\frac{F(c_0^2)}{f(c_0^2)}\right)(q_1^1+q_1^2)]\}dF(c_0^1)dF(c_0^2)$$

subject to

$$E_{c_0^k}\pi^j(\bar{c}_0)\geq 0,\ j=1,2$$

$$\frac{p_1^j-c^{jk}-\dfrac{a_o^k+a_t^k-2c_0}{2}}{p_1^j}=\frac{1}{\eta},\ j=1,2$$

Condition (13) results immediately by pointwise maximization.

To find condition (14) we maximize with respect to a_o^k (or a_t^k). This gives the first order condition:

$$-q_1^j\frac{dp_1^j}{da_o^k}+(1+\lambda)\left(q_1^j+(p_1^j-c^{jk})\frac{dq_1^j}{dp_1^j}\right)\frac{dp_1^j}{da_o^k}-\lambda\left(\frac{F(c_0^j)}{f(c_0^j)}+\frac{F(c_0^k)}{f(c_0^k)}\right)\frac{dq_1^j}{dp_1^j}\frac{dp_1^j}{da_o^k}=0$$

Solving for p_1^j gives

$$\frac{p_1^j-c^{jk}}{p_1^j}=\frac{\lambda}{1+\lambda}\frac{1}{\eta_1}+\frac{\lambda}{1+\lambda}\frac{1}{p_1^j(c_0)}\left[\frac{F(c_0^j)}{f(c_0^j)}+\frac{F(c_0^k)}{f(c_0^k)}\right]$$

Combining (10) with (14) gives the optimal access charges, equation (15). QED

According to Proposition 5, the price of the local calls is the same as in the case of non-competing networks. This is natural, because as demands for local and long-distance calls are independent, there is no additional reason to distort the price of local calls on top of giving the correct incentives. With respect to the access price, the regulator uses now this instrument to implicitly influence the price of long-distance calls. We have shown that without loss of generality the regulator can fix the originating access price equal to the terminating access price. In that case, according to Section 4.2, when networks are poor substitutes the optimal access price is lower than the marginal cost. We see now that under asymmetric information, two effects work in opposite directions. On the one hand, the access price is reduced with respect to the marginal cost of access to induce a reduction in the final price. This is the same effect as under complete information. On the other hand, the access price is increased with respect to the marginal cost of access to give incentives to reveal information. As usual, the distortion involves an increase in prices and a decrease in quantities of the inefficient types to reduce the rent of the more efficient ones. When both networks have the least possible marginal cost, the access charges (and therefore the retail price in the long-distance segment) are equal to the case of complete information. Moreover, comparing Proposition 2 and Proposition 5 we can observe that the same price structure for the long-distance segment can be obtained with regulation of the final prices or regulation of the access charges and competition on the final market. Because this is the best result the regulator can hope to achieve, we have shown that allowing competition in the long-distance segment is a way to implement the optimal regulation in the retail price.

6. Conclusions

The determination of the access price is now one of the key issues in telecommunications. Competition is being introduced in the long-distance segments while the local markets remain in general monopolized. A common fear is that networks may agree on high access charges in order to actually eliminate competition. Indeed, under some conditions, it has been proved that the access price can be an instrument to get the monopoly outcome. Therefore, regulation of the access charge is crucial in order to guarantee real competition. A common idea among regulators is that the access price should be made equal to the marginal cost of providing access.

The objective of this paper was to obtain a theory of access price regulation when competition is possible in the long-distance calls segment. As a general conclusion, we have shown that setting the access price equal to the marginal cost of giving access is not in general the best regulatory policy, even if the marginal cost is known.

Indeed, we have shown that when there is no competition between networks, any access price is optimal, because the regulator can directly control final prices. The access prices do not affect social welfare, because they constitute a transfer from one network to the other and this transfer does not create any distortion through the tax system. This is true both under complete or incomplete information about the marginal cost of giving access.

On the other hand, when networks compete in the long-distance segment, the access price plays a role in that it allows the regulator to indirectly control prices in the unregulated segment.

First, we showed that, there is no loss of generality in making the access prices for originating or terminating a call equal. The only thing that matters is the total access charges. Moreover, under complete information, if networks are poor substitutes, the optimal access price is lower than the marginal cost of access. This is because by lowering the access charge with respect to the marginal cost of access the regulator can induce a reduction of the retail price in the long-distance segment and, therefore, indirectly obtain the first-best (fully regulated monopoly) solution.

Under asymmetric information, two effects work in opposite directions to determine the optimal access price. On the one hand, access price is reduced with respect to marginal cost to induce a reduction in final price. This is the same effect that was found under complete information. On the other hand, access price is increased with respect to marginal cost to reduce the rent that has to be given-up in order to provide the correct incentives to reveal the cost information. Again, the regulator is able to replicate the fully regulated monopoly solution through the regulation of the access charges.

We can conclude, then, that introducing competition in the long-distance segment and regulating the access charges is a way of implementing the optimal regulatory policy.

7. Appendix

Proof of proposition 2.

Network *j*'s profit function is:

$$E_{c_0^k}\pi^j = \int_\Omega \begin{matrix} \{\frac{1}{2}\left[\left(p_0^j(\tilde{c}_0)-c_0^j\right)q_0^j(\tilde{c}_0)-f\right]+\alpha^j\left(p_1^j(\tilde{c}_0)-2c_0^j-c_1\right)q_1^j(\tilde{c}_0) \\ +\frac{1}{4}\alpha^k\left(a_o^j(\tilde{c}_0)+a_t^j(\tilde{c}_0)-2c_0^j\right)q_1^k(\tilde{c}_0) \\ -\frac{1}{2}\alpha^j\left(a_o^k(\tilde{c}_0)+a_t^k(\tilde{c}_0)-2c_0^j\right)q_1^j(\tilde{c}_0)+t^j(\tilde{c}_0)\}\, f\left(c_0^k\right)dc_0^k \end{matrix}$$

The Bayesian incentive constraints can be written as:

$$c_0^j = \arg\max_{\tilde{c}_0^j} E_{c_0^k}\pi^j(c_0,\tilde{c}_0),\ \forall\left(c_0^j,\tilde{c}_0^j\right)\in\Omega^2,\ j=1,2$$

By the envelope theorem, this is equivalent to

$$E_{c_0^k}\left(\frac{d\pi^j}{dc_0^j}\right) = -\frac{1}{2}E_{c_0^k}\left[q_0^j(c_0)+q_1^j(c_0)+q_1^k(c_0)\right] \qquad (16)$$

$$E_{c_0^k}\left(\frac{\partial^2\pi^j}{\partial c_0^j\partial\tilde{c}_0^j}\right)\geq 0 \qquad (17)$$

where $c_0 = (c_0^1, c_0^2)$, which gives:

$$E_{c_0^k}\pi^j(c_0) = \int_{\underline{c}_0}^{\bar{c}_0}\left\{\frac{1}{2}\int_{c_0^j}^{\bar{c}_0}\left[q_0^j\left(x,c_0^k\right)+q_1^j\left(x,c_0^k\right)+q_1^k\left(x,c_0^k\right)\right]dx\right\}dF\left(c_0^k\right)$$

The expected profit is decreasing in the marginal cost. Therefore, we can forget the participation constraints for all types except the least efficient one:

$$E_{c_0^k}\pi^j(\bar{c}_0) \geq 0,\ j = 1{,}2 \quad (18)$$

$$\max \iint_{\Omega^2} \{ \frac{1}{2} S\left(p_0^1, p_1^1\right) + \frac{1}{2} S\left(p_0^2, p_1^2\right) + \frac{1}{2}(1+\lambda)\left[\left(p_0^1 - c_0^1\right)q_0^1 + \left(p_1^1 - c_1^{11}\right)q_1^1 - f\right]$$
$$+ \frac{1}{2}(1+\lambda)\left[\left(p_0^2 - c_0^2\right)q_0^2 + \left(p_1^2 - c_1^{22}\right)q_1^2 - f\right] + \frac{1}{2}(1+\lambda)\left(c_0^1 - c_0^2\right)\left(q_1^1 - q_1^2\right) \qquad (19)$$
$$- \frac{\lambda}{2}\left(\pi^1 + \pi^2\right)\} dF\left(c_0^1\right) dF\left(c_0^2\right)$$

subject to (16), (17) and (18).

Solving (16) and (18) and replacing in (19) gives

$$\max \iint_{\Omega^2} \{ \frac{1}{2} S\left(p_0^1, p_1^1\right) + \frac{1}{2} S\left(p_0^2, p_1^2\right) + \frac{1}{2}(1+\lambda)\left[\left(p_0^1 - c_0^1\right)q_0^1 + \left(p_1^1 - c_1^{11}\right)q_1^1 - f\right]$$
$$+ \frac{1}{2}(1+\lambda)\left[\left(p_0^2 - c_0^2\right)q_0^2 + \left(p_1^2 - c_1^{22}\right)q_1^2 - f\right] + \frac{1}{2}(1+\lambda)\left(c_0^1 - c_0^2\right)\left(q_1^1 - q_1^2\right)$$
$$- \frac{\lambda}{2}\left[q_0^1 \frac{F\left(c_0^1\right)}{f\left(c_0^1\right)} + q_0^2 \frac{F\left(c_0^2\right)}{f\left(c_0^2\right)} + \left(\frac{F\left(c_0^1\right)}{f\left(c_0^1\right)} + \frac{F\left(c_0^2\right)}{f\left(c_0^2\right)}\right)\left(q_1^1 + q_1^2\right)\right]\} dF\left(c_0^1\right) dF\left(c_0^2\right)$$

Pointwise maximization with respect to (p_0^j, p_1^j), j = 1,2 gives the result. QED

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